

EFFECT OF THE STRATIFICATION
OF GASES IN A GAS ENGINE

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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An effect of the
stratification of gases in

AN EFFECT OF THE STRATIFICATION OF GASES IN A GAS ENGINE

A THESIS

PRESENTED BY

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TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

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Thesis

An Effect of the Stratification of the Gases in a Gas Engine

At the suggestion and under the direction of Mr. A. J. Frith, Associate Professor of Mechanical Engineering at the Armour Institute of Technology, a series of tests was made on a gas engine to determine the effects of stratifying the gases within the cylinder.

Description of the Engine

The engine on which the tests were made was a 6-3/4" x 11-15/16" horizontal, single cylinder, four cycle, water cooled Fairbanks Morse gas engine rated at 7 horse power when running at 250 revolutions per minute. Illuminating gas, taken directly from the city mains, was used for the fuel, in both series of tests, and by means of a reducing valve, was fed to the engine at atmospheric pressure.

Determination of the Calorific Value of the Fuel

The calorific value of the gas was determined about once an hour by means of a Junkers Calorimeter. This calorimeter is provided with a sensitive wet meter reading to one thousandths of a cubic foot, a regulator for maintaining constant pressure at the burner and sensitive thermometers graduated to tenths degrees Fahrenheit which, by estimation, may be read to one hundredths. In using the calorimeter, a constant flow of water was obtained, such that the difference in temperature of the in-going and out-going water was about 10 deg. F., while the gas was being burned at the rate of about four and one half cubic feet per hour. The issuing jacket water for a given period of time was weighed, as was also the products of combustion. The temperature and the pressure of the gas was obtained and from this the volume of the gas was reduced to standard condition, i.e., 62 deg. F. and 30" of mercury.

As all the conditions were allowed to become constant before any readings were taken and as great care was taken in effecting a complete absorption of the heat of the gas by the water, the errors due to radiation were inappreciable. The method of determining the "total" and the "effective" heating values of the gas is shown in the sample calculations.

Description of the First Series of Tests

A series of tests was first run on the engine under ordinary working conditions. Different loads were applied to the engine by means of a Prony Brake, and by this means the brake horse power was determined. A Crosby gas engine indicator was used to determine the indicated horse power. When a test was to be run, the engine was started and a predetermined load was put on. The engine was then allowed to run for some time in order that all conditions would become constant. In the meantime indicator cards were taken, and the mixture of gas and air was changed until it

was seen from the cards that the proper mixture was obtained. After obtaining this mixture and after the engine had warmed up and all conditions became constant, a half hour run was made. Readings were taken every five minutes of the inlet and outlet jacket water, weight of the jacket water, volume of the gas used, revolutions per minute and explosions per minute. Indicator cards were also taken every five minutes. The load on the brake was kept constant throughout the test. The temperature of the jacket water was averaged for the run and the average value was used in the calculations. By means of a continuous explosion counter, the total number of explosions for the half hour was obtained and from this value the explosions per minute were determined. The gas meter used was of the integrating type and the difference of the first and last readings was taken as the volume of the gas used. The jacket water was weighed in tanks mounted on scales and the difference in weights before and after the runs was used in the calculations. The readings of these instruments were taken every five minutes

to serve as a check as to the constancy of the conditions.

Method of Stratifying the Gases

By referring to the drawing it will be seen what device was used in attempting to stratify the gases and the method of placing this device in the cylinder over the inlet valve. This device consists of a thin plate on which were mounted twelve (12) vanes, set perpendicular to the plate. These vanes were arranged in a circle, the diameter to the back edges of them being just a fraction of an inch larger than the inlet valve. The whole device was placed over the inlet valve and screwed on to the head of the cylinder. Three screws were used and these were of such diameter and placed in such a position that each became part of a vane. The area between two consecutive vanes was made constant for the whole distance by increasing the height of the vane as the width became less and the combined area was designed to be such that it was about twenty five per cent. (25%) in excess of

the area of the inlet valve. This excess was allowed on account of the increased resistance placed in the path of the incoming gas. The shape of these vanes was such that the gas which entered the area between two consecutive vanes came in radially and left tangentially. This was designed to give the gas a rotating motion, rotating in a plane perpendicular to the entering gas and parallel to the head of the piston. The effect of this rotating motion was to keep a distinct strata of unburned gases throughout the cylinder and to keep the spark in this unburned portion.

Second Series of Tests

After this device was in place another series of tests was made similar to the first set. The readings of the same instruments were taken and used in the calculations in the same manner. An attempt was made to carry the same loads on the engine and to keep all other conditions as nearly similar to the first series as possible. As can be seen from the data sheets, a great quantity of

unburned gas passed through the cylinder without igniting in this second series of tests. An attempt was made to recover some of this lost gas by putting in a jump spark near the exhaust valve but the results of this attempt were not successful.

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Test of FAIRBANKS-MORSE Gas Engine
 Type HORIZONTAL-STATIONARY
 Size 6 3/4" x 11 15/16"
 Fuel Used ILLUMINATING GAS

Brake Circumference, ft. 13.61
 Dead Weight of Arm, lbs. 13.75
 On Scales, lbs. 4.25 = 18-13.75
 Total, lbs. 18

LOG OF TEST:

Barometer 29.64 HG. Date MARCH-27-1913.

TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	TEMPERATURE—DEGREES F				PRESSURE	WEIGHTS			HORSE POW'R	
						Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room		Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading
RPM.															
NET LOAD = 4.25 LBS.															
3:40	240	144		4439		40	82	61.5		29.69		518		4.25	
3:45	240	278		495		40	82	61.5		29.69		546		4.25	
3:50	240	404		544		40	81	61.5		29.69		578		4.25	
3:55	240	545		602		40	82	61.5		29.69		608		4.25	
4:00	240	688		661		40	84	61.5		29.69		635		4.25	
4:05	240	829		720		40	85	61.5		29.69		661		4.25	
4:10	240	970		777		40	86	61.5		29.69		688		4.25	
AVER.	240	27.53		676		40	83.1	61.5		29.69		170		4.25	.238 2.73
NET LOAD = 21.25 LBS.															
4:30	240	19838		5123		40	112			29.69		526		21.25	
4:35	240	20068		215		40	116			29.69		549		21.25	
4:40	240	20291		203		40	118			29.69		570		21.25	
4:45	240	20515		393		40	120			29.69		591		21.25	
4:50	240	20738		482		40	122			29.69		610		21.25	
4:55	240	20960		570		40	124			29.69		630		21.25	
5:00	240	21181		659		40	125			29.69		649		21.25	
AVER.	240	44.73		1072		40	119.6			29.69		123		21.25	2.10 4.43

REMARKS:

RUN WITHOUT "STRATIFIER"

Observer.

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Brake Circumference, ft. 13.61
Dead Weight of Arm, lbs. 13.75
On Scales, lbs. $50 - 13.75 = 36.25$
Total, lbs. 50

TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	TEMPERATURE—DEGREES F			PRESSURE	WEIGHTS	HORSE POWER
						Entering Jacket Water			Gas at Meter, In. Mer.		
						Issuing Jacket Water			At Eng., In. Water		
						Gas at Meter			Jacket Water		
						Room			Scale Reading		
						Exhaust			Brake Load, Net		
									B. H. P.		
									I. P. H.		

Wid.

NET LOAD = 36.25 LBS.

2:22 255 7955	8266	38	79.5	61	29.67	535	36.25
2:27 255 8289	394	38	76	61	29.67	620	36.25
2:32 255 8628	525	38	76	61	29.67	704	36.25
2:37 255 8964	656	38	75	61	29.67	785	36.25
2:42 255 9292	784	38	74	61	29.67	867	36.25
2:47 255 9621	915	38	74	61	29.67	950	36.25
2:52 255 9954	9046	38	74	61	29.67	1028	36.25
AVER. 255 66.66	1560	38	75.4	61	29.67	493	36.25 381 636

NET LOAD = 68.25 LBS.

3:15 254 2273	59953	38	92	62.5	29.67	535	68.25
3:20 254 2855	60180	38	94	62.5	29.67	620	68.25
3:25 254 3452	60420	38	97	62.5	29.67	698	68.25
3:30 254 4056	60651	38	98	62.5	29.67	776	68.25
3:35 254 4661	61089	38	97	62.5	29.67	860	68.25
3:40 254 5278	61130	38	98	62.5	29.67	940	68.25
3:45 254 5905	61385	38	98	62.5	29.67	1021	68.25
AVR. 254 12106	2864	38	96.4	62.5	29.67	486	68.25 7.15 10.32

REMARKS:

RUN WITHOUT STRATIFIER

Observer

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Test of FAIRBANKS-MORSE Gas Engine. Date MARCH-27-1913

Size 6 $\frac{3}{4}$ x 11 $\frac{15}{16}$ Type HORIZONTAL-STA. Clearance 193.363 cubic inches.

Rating 7 B.H.P. at 250 R. P. M. Clearance 45 % piston displacement.

Indicator Used CROSBY Maximum Compression 50 lbs. per sq. in.

Scale Spring 160 #

DATA FROM CARDS

No.	EXPLOSIONS	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I. H. P.	B. H. P.	MECHANICAL EFFICIENCY
	P. M.						
1		1.67	3.39				
2		1.69					
3		1.62					
4		1.61					
5		1.62					
6		1.67					
7		1.59					
AVER.	27.53	1.624	3.39	76.70	2.73	.42	15.4%
8		1.65	3.39				
9		1.59					
10		1.59					
11		1.63					
12		1.64					
13		1.63					
14		1.60					
AVER.	44.73	1.62	3.39	76.50	4.43	2.1	47.5%

REMARKS:

RUN WITHOUT "STRATIFIER"

Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of FAIRBANKS - MORSE Gas Engine. Date MARCH-28-1913

Size $6\frac{3}{4}$ " x $11\frac{15}{16}$ " Type HORIZONTAL - STA. Clearance 193.363 cubic inches.

Rating 7 B.H.P. at 250 R. P. M. Clearance 45 % piston displacement.

Indicator Used CROSBY. Maximum Compression 52.5 lbs. per sq. in.

Scale Spring 160 #

DATA FROM CARDS

No.	<i>Explosions</i> P. M.	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I. H. P.	B. H. P.	MECHANICAL EFFICIENCY
15		1.56	3.39				
16		1.53					
17		1.57					
18		1.58					
19		1.54					
20		1.58					
21		1.56					
AVER.	66.66	1.56	3.39	73.70	6.36	3.81	60.0%
22		1.43	3.39				
23		1.39					
24		1.39					
25		1.39					
26		1.40					
27		1.41					
28		1.40					
AVER.	121.06	1.40	3.39	66.0	10.32	7.15	69.3%

REMARKS:

RUN WITHOUT "STRATIFIER"

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DETERMINATION OF THE CALORIFIC VALUE OF GAS, BY JUNKER'S CALORIMETER

Date MARCH-27-1913

Kind of gas ILLUMINATING GAS

Source CITY MAINS

	NUMBER OF RUN,	1	2	3	4
Time starting run,		4:21			
Time ending run,		4:26			
Duration of run, minutes,		5			
Temperature of chimney, °C,		7.78			
Temperature of air, °C,		—			
Temperature of gas, at meter, °C,		16.1			
Temperature of entering jacket water, °C,		2.67			
Temperature of issuing jacket water, °C,		8.45			
Range of temperature,		5.78			
Pressure of atmosphere, inches mercury,		29.64			
Pressure of gas at meter, inches mercury,		29.67			
Pressure of gas at burner, inches water,		404			
Weight of discharge tank and water, lbs.,		23.20			
Weight of discharge tank, empty, lbs.,		4.96			
Weight of jacket water, lbs.,		18.24			
Reading of meter, beginning,		.083			
Reading of meter, end,		.412			
Total gas consumed, cu. ft.,		.329			
Total gas consumed reduced to 30" Hg. and 62° F., cu. ft.,		.327			
Cu. ft. gas per hour,		3.924			
Lbs. steam condensed per cu. ft. gas,		.0331			
Calorific value of gas, B. T. U., total,		580			
Calorific value of gas, B. T. U., effective,		546.9			

REMARKS:

RUN WITHOUT "STRATIFIER"

Observer _____

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

13

DETERMINATION OF THE CALORIFIC VALUE OF GAS, BY JUNKER'S CALORIMETER

Date MARCH - 28 - 1913

Kind of gas ILLUMINATING GAS.

Source CITY MAINS.

	NUMBER OF RUN,	1	2	3	4
Time starting run,		1:52	3:05		
Time ending run,		1:57	3:10		
Duration of run, minutes,		5	5		
Temperature of chimney, °C,		7.78	7.78		
Temperature of air, °C,		—	—		
Temperature of gas, at meter, °C,		16.1	16.95		
Temperature of entering jacket water, °C,		2.67	2.67		
Temperature of issuing jacket water, °C,		8.45	7.61		
Range of temperature,		5.78	4.94		
Pressure of atmosphere, inches mercury,		29.64	29.64		
Pressure of gas at meter, inches mercury,		29.67	29.67		
Pressure of gas at burner, inches water,		4.04	4.04		
Weight of discharge tank and water, lbs.,		23.20	25.63		
Weight of discharge tank, empty, lbs.,		4.96	7.33		
Weight of jacket water, lbs.,		18.24	18.30		
Reading of meter, beginning,		.083	.077		
Reading of meter, end,		4.12	4.51		
Total gas consumed, cu. ft.,		.329	.374		
Total gas consumed reduced to 30" Hg. and 62° F., cu. ft.,		.327	.371		
Cu. ft. gas per hour,		3.924	4.452		
Lbs. steam condensed per cu. ft. gas,		.0331	.0364		
Calorific value of gas, B. T. U., total,		580	439		
Calorific value of gas, B. T. U., effective,		546.9	402.6		

REMARKS:

"RUN WITHOUT STRATIFIER"

Observer _____

Test of *FAIRBANKS-MORSE* Gas EngineDate *MARCH-27-1913*Kind of Fuel *ILLUMINATING GAS*

No. OF RUN		1	2	3	4
Duration of test,	hours.	.5	.5		
Gas consumed,	cu. ft.	33.8	53.6		
Air consumed,	cu. ft.	—	—		
*Calorific value of gas, total,	B. T. U. per cu. ft.	580	580		
Calorific value of gas, effective.	B. T. U. per cu. ft.	546.9	546.9		
Jacket water supplied,	lbs.	170	123		
*Gas per hour,	cu. ft.	67.0	105.8		
*Air per hour,	cu. ft.	—	—		
Jacket water per hour,	lbs.	340	246		
Gas at meter,	ins. mercury.	29.69	29.69		
Barometer,	ins. mercury.	29.64	29.64		
Gas at engine,	ins. water.	—	—		
Jacket water {	Inlet	deg. F.	40	40	
	Outlet,	deg. F.	83.1	119.6	
Gas at meter,	deg. F.	61.5	63.0		
Air in room,	deg. F.	—	—		
Revolutions per minute,	rev.	240	240		
Explosions per minute,		27.53	44.73		
Pressure in lbs. per sq. in. above atmosphere					
(a) Maximum pressure,		205	200		
(b) Pressure just before ignition,		50	50		
(c) Pressure at end of expansion,		37.5	37.5		
(d) Exhaust pressure,		0	0		
Mean effective pressure,	lbs. per sq. in.	76.70	76.50		
Builders' rating,	H. P.	7	7		
Actual indicated H. P.,	H. P.	2.73	4.43		
Actual brake H. P.	H. P.	.42	2.10		
Mechanical Efficiency	%	15.4	47.50		
B. T. U. per I. H. P. per hr.,		13,780	13,050		
B. T. U. per B. H. P. per hr.,		89,600	27,500		
*Cu. ft. gas per I. H. P.,		24.5	23.9		
*Cu. ft. gas per B. H. P.,		15.90	50.4		
Heat equivalent of I. H. P., efficiency	per cent.	18.45	19.50		
Heat rejected in jacket water	per cent.	39.00	33.90		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	per cent.	42.55	46.60		
Heat equivalent of B. H. P. efficiency	per cent.	2.84	9.25		

*All gas volumes reduced to 62° F. and 30 inches mercury.

RUN WITHOUT "STRATIFIER"

Observer

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Test of FAIRBANKS-MORSE Gas Engine

Date MARCH-28-1913

Kind of Fuel ILLUMINATING GAS.

No. OF RUN		1	2	3	4
Duration of test,	hours.	.5	.5		
Gas consumed,	cu. ft.	780	1432		
Air consumed,	cu. ft.	—	—		
*Calorific value of gas, total,	B. T. U. per cu. ft.	580	439		
Calorific value of gas, effective.	B. T. U. per cu. ft.	546.9	402.6		
Jacket water supplied,	lbs.	493	486		
*Gas per hour,	cu. ft.	154.2	2830		
*Air per hour,	cu. ft.	—	—		
Jacket water per hour,	lbs.	986	972		
Gas at meter,	ins. mercury.	29.67	29.67		
Barometer,	ins. mercury.	29.64	29.64		
Gas at engine,	ins. water.	—	—		
Jacket water { Inlet	deg. F.	38	38		
{ Outlet,	deg. F.	75.4	96.4		
Gas at meter,	deg. F.	61	62.5		
Air in room,	deg. F.	—	—		
Revolutions per minute,	rev.	255	254		
Explosions per minute,		66.66	121.06		
Pressure in lbs. per sq. in. above atmosphere					
(a) Maximum pressure,		210	215		
(b) Pressure just before ignition,		50	52.5		
(c) Pressure at end of expansion,		37.5	35.0		
(d) Exhaust pressure,		0	0		
Mean effective pressure,	lbs. per sq. in.	73.70	66.0		
Builders' rating,	H. P.	7	7		
Actual indicated H. P.,	H. P.	6.36	10.32		
Actual brake H. P.	H. P.	3.81	7.15		
Mechanical Efficiency	%	60	69.30		
B. T. U. per I. H. P. per hr.,		132500	110200		
B. T. U. per B. H. P. per hr.,		22100.0	159500		
*Cu. ft. gas per I. H. P.,		24.3	27.4		
*Cu. ft. gas per B. H. P.,		40.6	39.6		
Heat equivalent of I. H. P., efficiency	per cent.	19.15	23.10		
Heat rejected in jacket water	per cent.	43.70	49.70		
Heat rejected in exhaust and lost through radiation and incomplete combustion,	per cent.	37.15	21.20		
Heat equivalent of B. H. P. efficiency	per cent.	11.45	15.95		

*All gas volumes reduced to 62° F. and 30 inches mercury.

RUN WITHOUT "STRATIFIER"

Observer _____

MECHANICAL ENGINEERING LABORATORY

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Test of FAIRBANKS-MORSE Gas Engine
 Type HORIZONTAL-STATIONARY
 Size 6 3/4" x 11 1/2"
 Fuel Used ILLUMINATING GAS.

Brake Circumference, ft. 13.61
 Dead Weight of Arm, lbs. 13.75
 On Scales, lbs. _____
 Total, lbs. _____

LOG OF TEST:

Barometer 29.08 Date APRIL-3-1913

TIME	REVOLUTION COUNTER	EXPLOSIONS PER MINUTE	REVOLUTIONS PER MINUTE	GAS METER	CUBIC FEET GAS PER HR.	TEMPERATURE—DEGREES F				PRESSURE		WEIGHTS		HORSE POWER			
						Entering Jacket Water	Issuing Jacket Water	Gas at Meter	Room	Exhaust	Gas at Meter, In. Mer.	At Eng., In. Water	Jacket Water	Scale Reading	Brake Load, Net	B. H. P.	I. P. H.
R.P.M.						NET LOAD = 5.25 LBS.											
3:00	250	8729	4331		41	62	70			29.12		537		5.25			
3:05	250	8928	405		41	64	70			29.12		602		5.25			
3:10	250	9123	480		41	65	70			29.12		674		5.25			
3:15	250	9314	555		41	65	70			29.12		747		5.25			
3:20	250	9507	629		41	65	70			29.12		818		5.25			
3:25	250	9698	703		41	65	70			29.12		885		5.25			
3:30	250	9887	776		41	65	70			29.12		960		5.25			
AVER.	250	38.6		890	41	64.4	70			29.12		423		5.25	54	2.58	
						NET LOAD = 21.25 LBS.											
3:56	250	1716	5451		41	88	70			29.12		537		21.25			
4:01	250	2077	5582		41	88	70			29.12		602		21.25			
4:06	250	2430	5712		41	87	70			29.12		665		21.25			
4:11	250	2785	5841		41	86	70			29.12		729		21.25			
4:16	250	3145	5971		41	86	70			29.12		797		21.25			
4:21	250	3517	6105		41	88	70			29.12		858		21.25			
4:26	250	3887	6239		41	87	70			29.12		922		21.25			
AVER.	250	72.4	1576	41	87.1	70				29.12		385		21.25	2.18	4.33	
						NET LOAD = 38.25 LBS.											
4:47	250	6112	7051		42	107	70			29.12		528		38.25			
4:52	250	6686	7250		42	108	70			29.12		587		38.25			
4:57	250	7248	7440		42	110	70			29.12		650		38.25			
5:02	250	7814	7630		42	111	70			29.12		710		38.25			
5:07	250	8380	7840		42	111	70			29.12		766		38.25			
5:12	250	8946	8012		42	110	70			29.12		827		38.25			
5:17	250	9542	8235		42	110	70			29.12		886		38.25			
AVER.	250	114.3	2368	42	109.5	70				29.12		358		38.25	3.93	6.78	

REMARKS:

RUN WITH 'STRATIFIER'

Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

Test of FAIRBANKS-MORSE Gas Engine.Date APRIL - 3-1913Size 6 $\frac{3}{4}$ " x 11 $\frac{15}{16}$ " Type HORIZONTAL-STA Clearance 186.25 cubic inches.Rating 7 B. H. P. at 250 R. P. M. Clearance 43.5 % piston displacement.Indicator Used CROSBY Maximum Compression 50 lbs. per sq. in.Scale Spring 160 #

DATA FROM CARDS

No.	EXPLOSIONS ■ P. M.	AREA	LENGTH OF CARD	MEAN EFFECTIVE PRESSURE	I. H. P.	B. H. P.	MECHANICAL EFFICIENCY
1		1.08	3.39				
2		1.07					
3		1.09					
4		1.08					
5		1.08					
6		1.07					
7		1.08					
AVER.	38.6	1.08	3.39	51.6	2.58	5A1	21.0%
8		.97	3.39				
9		.98					
10		.99					
11		1.02					
12		.98					
13		.98					
14		.98					
AVER.	72.4	.985	3.39	46.5	4.33	2.18	50.4%
15		.96	3.39				
16		.94					
17		.98					
18		.99					
19		.97					
20		.99					
21		.96					
AVER.	114.3	.97	3.39	45.8	6.78	3.93	58.0%

REMARKS:

RUN WITH "STRATIFIER"

Observer.

MECHANICAL ENGINEERING LABORATORY

ARMOUR INSTITUTE OF TECHNOLOGY

18

DETERMINATION OF THE CALORIFIC VALUE OF GAS, BY JUNKER'S CALORIMETER

Date APRIL - 3 - 1913

Kind of gas ILLUMINATING GAS

Source CITY MAINS

	NUMBER OF RUN,	1	2	3	4
Time starting run,		3.35			
Time ending run,		3.40			
Duration of run, minutes,		5			
Temperature of chimney, °C,		7.22°			
Temperature of air, °C,		—			
Temperature of gas, at meter, °C,		21.10°			
Temperature of entering jacket water, °C,		5.61°			
Temperature of issuing jacket water, °C,		9.73°			
Range of temperature,		4.12°			
Pressure of atmosphere, inches mercury,		29.08			
Pressure of gas at meter, inches mercury,		29.12			
Pressure of gas at burner, inches water,		29.08			
Weight of discharge tank and water, lbs.,		23.0			
Weight of discharge tank, empty, lbs.,		5.13			
Weight of jacket water, lbs.,		17.87			
Reading of meter, beginning,		.097			
Reading of meter, end,		4.38			
Total gas consumed, cu. ft.,		.341			
Total gas consumed reduced to 30" Hg. and 62° F., cu. ft.,		.326			
Cu. ft. gas per hour,		3.925			
Lbs. steam condensed per cu. ft. gas,		.0427			
Calorific value of gas, B. T. U., total,		408			
Calorific value of gas, B. T. U., effective,		365.3			

REMARKS:

RUN WITH "STRATIFIER"

Observer

MECHANICAL ENGINEERING LABORATORY

19

ARMOUR INSTITUTE OF TECHNOLOGY

Test of FAIRBANKS-MORSE Gas Engine

Date APRIL-3-1913

Kind of Fuel ILLUMINATING GAS

No. OF RUN		1	2	3	4
Duration of test,	hours.	.5	.5	.5	
Gas consumed,	cu. ft.	44.5	78.8	118.4	
Air consumed,	cu. ft.				
*Calorific value of gas, total,	B. T. U. per cu. ft.	408	408	408	
Calorific value of gas, effective.	B. T. U. per cu. ft.	365	365	365	
Jacket water supplied,	lbs.	423	385	358	
*Gas per hour,	cu. ft.	84.9	1500	2260	
*Air per hour,	cu. ft.				
Jacket water per hour,	lbs.	846	770	716	
Gas at meter,	ins. mercury.	29.12	29.12	29.12	
Barometer,	ins. mercury.	29.08	29.08	29.08	
Gas at engine,	ins. water.				
Jacket water {	Inlet	deg. F.	41	41	42
	Outlet,	deg. F.	64.4	87.1	109.5
Gas at meter,	deg. F.	70	70	70	
Air in room,	deg. F.				
Revolutions per minute,	rev.	250	250	250	
Explosions per minute,		38.6	77.4	114.3	
Pressure in lbs. per sq. in. above atmosphere					
(a) Maximum pressure,		230	205	200	
(b) Pressure just before ignition,		50	50	50	
(c) Pressure at end of expansion,		25	25	20	
(d) Exhaust pressure,		0	0	0	
Mean effective pressure,	lbs. per sq. in.	51.6	46.5	45.8	
Builders' rating,	H. P.	7	7	7	
Actual indicated H. P.,	H. P.	2.58	4.33	6.78	
Actual brake H. P.	H. P.	.541	2.18	3.93	
Mechanical Efficiency	%	21	50.4	58	
B. T. U. per I. H. P. per hr.,		120000	12660.0	12160.0	
B. T. U. per B. H. P. per hr.,		573000	25100.0	210000	
*Cu. ft. gas per I. H. P.,		32.9	34.8	33.4	
*Cu. ft. gas per B. H. P.,		156.8	68.8	57.6	
Heat equivalent of I. H. P., efficiency	per cent.	21.2	20.5	20.90	
Heat rejected in jacket water	per cent.	64.0	64.90	58.60	
Heat rejected in exhaust and lost through radiation and incomplete combustion,	per cent.	14.8	14.95	20.50	
Heat equivalent of B. H. P. efficiency	per cent.	4.44	10.12	12.10	

*All gas volumes reduced to 62° F. and 30 inches mercury.

RUN WITH "STRATIFIER"

Observer

MECHANICAL ENGINEERING LABORATORY

20

ARMOUR INSTITUTE OF TECHNOLOGY

Test of FAIRBANKS-MORSE Gas Engine

Date APRIL-3-1913

Kind of Fuel ILLUMINATING GAS

USING B.T.U. VALUE OF
580 INSTEAD OF THE
VALUE WE OBTAINED OF 408

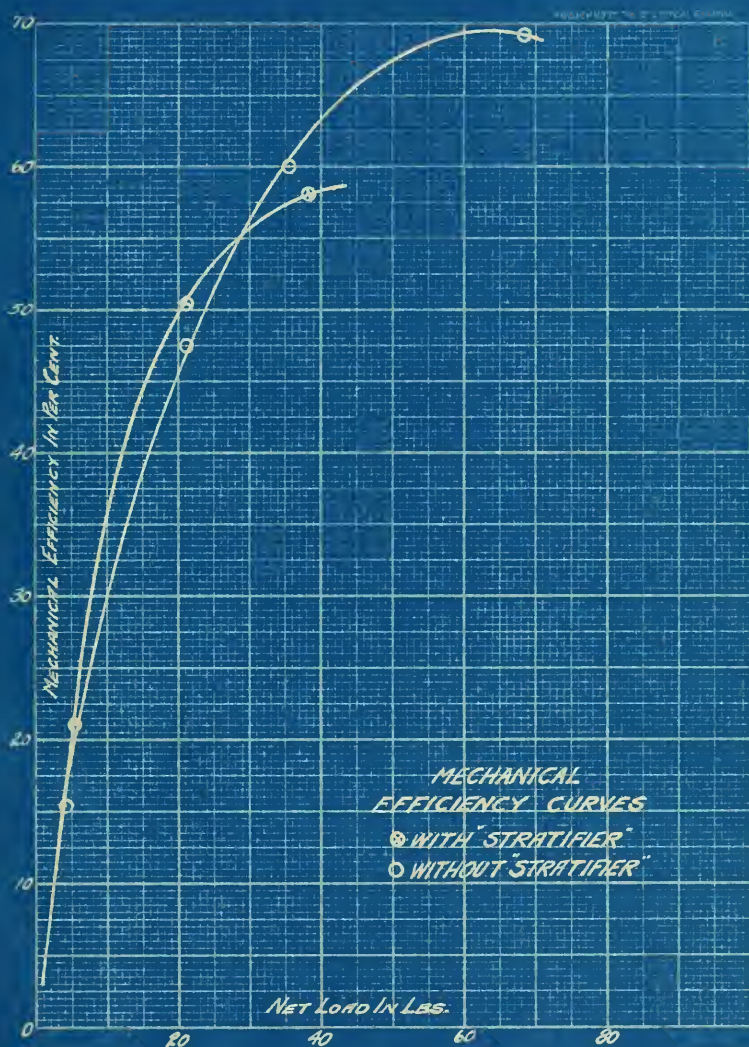
NO. OF RUN		1	2	3	4
Duration of test,	hours.	.5	.5	.5	
Gas consumed,	cu. ft.	44.5	72.8	112.4	
Air consumed,	cu. ft.	—	—	—	
*Calorific value of gas, total,	B. T. U. per cu. ft.	580	580	580	
Calorific value of gas, effective.	B. T. U. per cu. ft.	546.9	546.9	546.9	
Jacket water supplied,	lbs.	423	385	358	
*Gas per hour,	cu. ft.	84.9	150	226	
*Air per hour,	cu. ft.	—	—	—	
Jacket water per hour,	lbs.	846	770	716	
Gas at meter,	ins. mercury.	29.12	29.12	29.12	
Barometer,	ins. mercury.	29.08	29.08	29.08	
Gas at engine,	ins. water.	—	—	—	
Jacket water {	Inlet	41	41	42	
	Outlet,	64.4	87.1	109.5	
Gas at meter,	deg. F.	70	70	70	
Air in room,	deg. F.				
Revolutions per minute,	rev.	250	250	250	
Explosions per minute,		386	77.4	114.3	
Pressure in lbs. per sq. in. above atmosphere					
(a) Maximum pressure,		230	205	200	
(b) Pressure just before ignition,		50	50	50	
(c) Pressure at end of expansion,		25	25	20	
(d) Exhaust pressure,		0	0	0	
Mean effective pressure,	lbs. per sq. in.	51.6	46.5	45.8	
Builders' rating,	H. P.	7	7	7	
Actual indicated H. P.,	H. P.	2.58	4.33	6.78	
Actual brake H. P.,	H. P.	.541	2.18	3.93	
Mechanical Efficiency	%	21	50.4	58	
B. T. U. per I. H. P. per hr.,		18,000	18,950	18,250	
B. T. U. per B. H. P. per hr.,		85,900	37,600	31,400	
*Cu. ft. gas per I. H. P.,		32.9	34.8	33.4	
*Cu. ft. gas per B. H. P.,		156.8	68.8	57.6	
Heat equivalent of I. H. P., efficiency	per cent.	14.12	13.42	13.95	
Heat rejected in jacket water	per cent.	64.40	64.90	58.60	
Heat rejected in exhaust and lost through radiation and incomplete combustion,	per cent.	21.48	21.68	27.45	
Heat equivalent of B. H. P. efficiency	per cent.	2.96	6.77	8.11	

*All gas volumes reduced to 62° F. and 30 inches mercury.

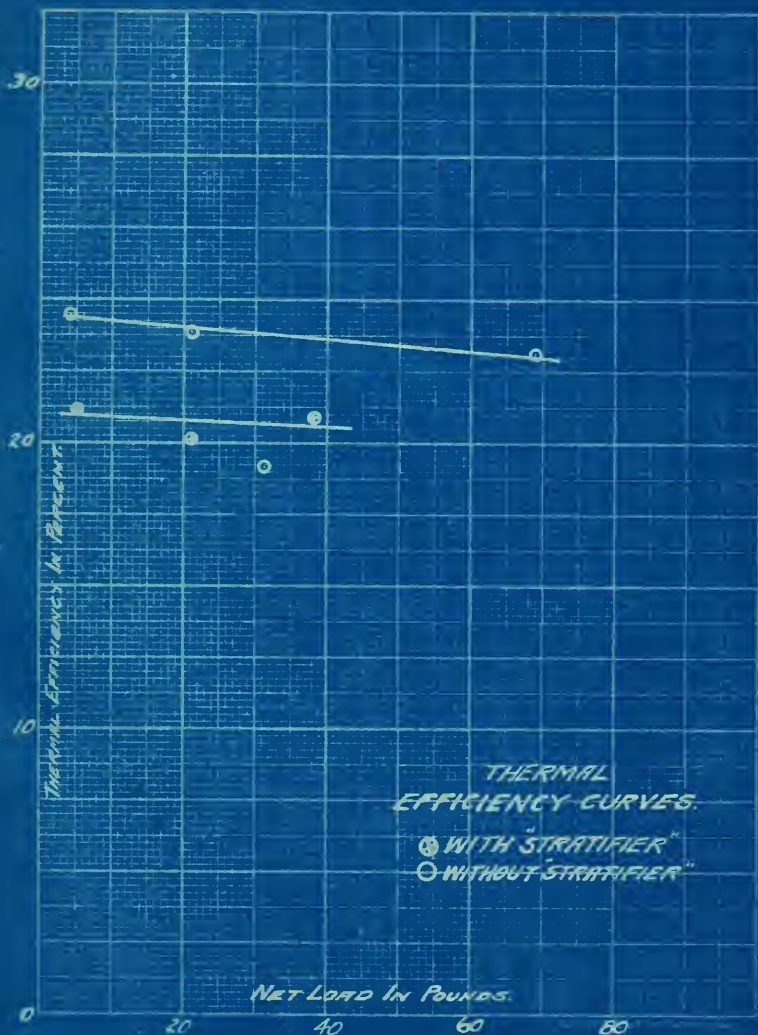
RUN WITH "STRATIFIER"

Observer _____

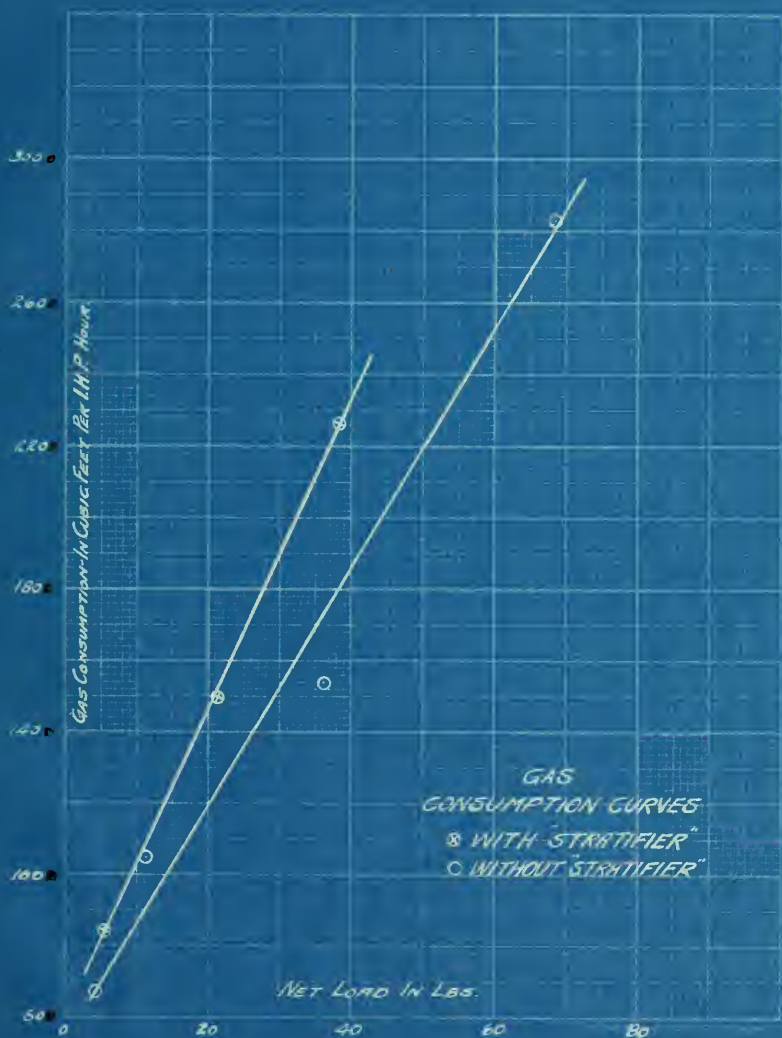














WITHOUT STRATIFIER



160° SPRING

WITH STRATIFIER



REPRESENTATIVE INDICATOR CARDS.

WITHOUT "STRATIFIER"



VOLUMETRIC EFFICIENCY- 91.8 PER CENT.

40[#] SPRING.

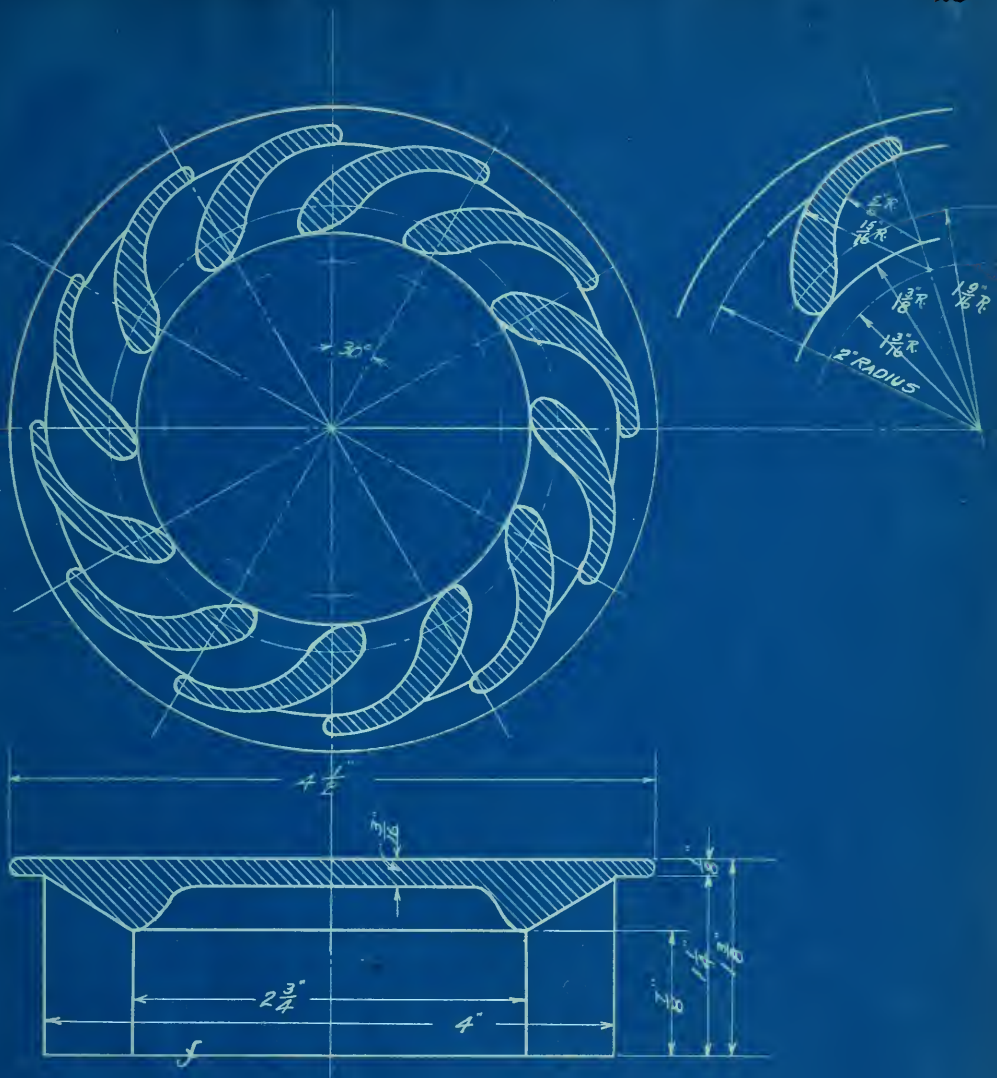
WITH "STRATIFIER"



VOLUMETRIC EFFICIENCY- 89.8 PERCENT.

REPRESENTATIVE LIGHT SPRING CARDS.





"STRATIFIER"



SKETCH OF
PLAN VIEW OF ENGINE SHOWING
ARRANGEMENT OF
VALVES AND "STRATIFIER."

Comparison of the Tests

As will be seen from the data, after the "stratifier" was in place, the engine used much more gas than under the same load when the device was not used. This loss is due to two causes, viz:-a greater loss due to the heat given to the jacket water and to incomplete combustion.

By referring to the drawing of the engine showing the relative position of the valves, it will be seen that there is a large space into which the gases enter before being exhausted. An explanation of the waste of gas due to incomplete combustion can therefore be made by saying that the strata of unburned gas, as it entered the cylinder, was forced up against the wall of this exhaust space and a strata of burned gas, which would not allow the unburned gas to ignite, lay between this unburned gas and the igniter.

As the volumetric efficiency of the engine was practically the same in both cases, on account of this unburned strata of gas, more explosions on the quantity of gas which did the work were necessary to carry the same load than in the first

series of tests. On account of this very poor thermal efficiency the horse power developed within the cylinder of the engine was necessarily reduced and hence the engine with the "stratifier" in place would not carry the same load that it would when the "stratifier" was left out. This high rate of gas consumption in the second series of tests greatly increased the values of the gas per I. H. P. and gas per B.H.P.

The additional log forms indicate the results that we would have obtained on those runs, for which we obtained a low calorific value of our fuel, had the B. T. V. value of the fuel been up to the grade of the gas that was supplied to the engine in the other runs.

It might be said in conclusion that as the arrangement of the valves in this engine is such as not to allow the gases to occupy the positions in which the "stratifier" is supposed to keep them, a positive result of this experiment has not been obtained, but as this engine is built in such a way that the arrangement of the valves cannot be changed, any further attempt to experiment with this device on this engine was forestalled.

Sample Calculations.

All values substituted in formulas taken from run #1 series # 1.

The calorific value of the fuel was determined from the formula

$$\text{Total heating value} = H = \frac{(t_2 - t_1) \times 1.8 \times W}{V_2}$$

$$\text{Effective heating value} = H - (1000 \times S)$$

where

$t_2 - t_1$ = range in temp. of jacket water
in degrees Centigrade.

W = pounds of water discharged.

S = weight of condensed steam in pounds.

$$V_2 = \frac{P_1 T_2}{P_2 T_1} \times V_1$$

where

P_1 = atmospheric pressure plus pressure
Of gas at meter.

P_2 = 30 inches of mercury.

T_1 = temp. of gas at meter in deg.F. plus 460

T_2 = 62 deg. F. plus 460.

$$t_2 - t_1 = 5.78$$

$$V = 18.24$$

$$V_2 = 0.329 \times \frac{29.67 \times 522}{30 \times 521.5} = 0.327 \text{ cu. ft.}$$

$$S = 0.0331$$

therefore

$$\text{Total. heat. val.} = \frac{5.78 \times 1.8 \times 18.24}{0.327} \quad 580 \text{ B.t.u./cu.ft.}$$

$$\text{Eff. heat. val.} = 580 - (1000 \times 0.0331) \quad 546.9 \quad "$$

The gas used per hour was 67.6 cu. ft at 61.5 deg.F. and 29.69 inches of mercury. This was reduced to standard conditions, i.e., 62 deg. F. and 30 in. of mercury by the formula

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

substituting

$$\frac{29.69 \times 67.6}{521.5} = \frac{30 \times V_2}{522}$$

solving

$$V_2 = 67.0 \text{ cu. ft.}$$

$$\text{The Indicated Horse Power} = \frac{P L A N}{33000}$$

where

P = mean effective pressure in lbs./sq.in.

L = length of stroke in feet.

A = area of piston in sq. in.

N = number of explosions per minute.

substituting the values

$$P = 76.70$$

$$L = 11.94$$

$$A = 35.79$$

$$N = 27.53$$

$$\text{The I. H. P.} = \frac{76.70 \times 11.94 \times 35.79 \times 27.53}{33000} = 2.73$$

$$\text{The Brake Horse Power} = \frac{2 \times \pi \times R \times P \times N}{33000}$$

where

R = length of the brake arm in feet.

L = net load on scales.

N = number of revolutions per minute.

substituting the values

$$R = 2.17$$

$$P = 4.25$$

$$N = 240$$

$$\text{The B. H. P.} = \frac{2 \times \pi \times 2.17 \times 4.25 \times 240}{33000} = 0.42$$

$$\text{The Mechanical Efficiency} = \frac{\text{B.H.P.}}{\text{I.H.P.}} = \frac{.42}{2.73} = 15.4 \%$$

$$\text{The B.t.u. / I.H.P. / hr.} = \frac{\text{total B.t.u. / hr.}}{\text{I.H.P.}}$$

$$\frac{546.9 \times 67}{2.73} = 13,780$$

The heat equivalent of the I.H.P. efficiency in per cent

$$\begin{aligned}
 &= \frac{2545 \text{ I. H. P.}}{\text{total B.t.u.}} \times 100 \\
 &= \frac{2545 \times 2.73 \times 100}{67 \times 546.9} = 18.45 \%
 \end{aligned}$$

The heat rejected in the jacket water in per cent

$$\begin{aligned}
 &= \frac{\text{weight of water} \times \text{range in temperature}}{\text{total B.t.u. supplied / hr.}} \times 100 \\
 &= \frac{340 \times 43.1}{67 \times 546.9} \times 100 = 39.00 \%
 \end{aligned}$$

The heat rejected in the exhaust and lost through
incomplete combustion and radiation, in per cent

$$\begin{aligned}
 &= \frac{100 - (18.45 + 39)}{100} \times 100 = 42.55 \%
 \end{aligned}$$

